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Abstract:

The assignment selection criteria used to reassign AF personnel is examined. A mathematical programming model is presented to allocate the personnel resource. The model uses a linear programming algorithm to perform the allocation process. The changability and adaptability of the procedure is discussed.

Keywords: Mathematical programming, Linear programming, and Resource allocation.

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PERSONNEL ALLOCATION
USING A
MATHEMATICAL PROGRAMMING
MODEL

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UNIVERSITY OF ARIZONA
TUCSON ARIZONA

10 APRIL

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CONTENTS:

1.0 BACKGROUND.

The Department of Defense is organized with two distinct lines of control. Operational control to deploy and exercise combat forces, and administrative control to train and equip the units of each service. Operational control of service units crosses service boundaries and relates strictly to their use for national defense. For example, a Navy admiral commands the US forces in the Pacific area. He has operational control of all Army, Navy, Marine and Air Force combat forces in the Pacific area. Administrative control is totally within the service branch. Each service is responsible for training and equipping its units to perform a specific function in support of the operational commanders. In the Pacific area for example, the Air Force is responsible for training and equipping Air Force units. The Air Force units are under the operational control of the commander of the Pacific area for use in combat.

1.1 AF RESOURCES AND THE COSTS.

United States Air Force (AF) units are located through out the free world. Headquarters AF is responsible for not only training and equipping these units, but also providing the people necessary to perform the unit's function. There are over 650,000 persons in the AF (civilian workers are not included). There are over 20,000 active units in the AF. For a unit to perform a specific function, the unit is authorized a specific number of personnel with specific occupational skills and specialties. This suggests the magnitude of the resource allocation problem.

AF units located outside the Continental United States (CONUS) are relatively permanent in location. The personnel to operate the unit are rotated to and from the CONUS. Personnel assigned outside the CONUS spend a specific length of time at a location overseas and then return to the CONUS. The length of time spent at an overseas location is the tour length for that location. Tour lengths usually vary from 12 to 36 months. Personnel assigned to CONUS units form a resource pool from which overseas vacancies are filled through the assignment allocation process. Some persons like to serve in overseas locations, some do not. Some overseas assignments are highly desired, some are not. The costs of assigning and maintaining personnel in overseas areas is high by most any standard. The length of an overseas tour usually varies with the cost of maintaining dependent personnel at that overseas location. Tour lengths are longer for the service member if accompanied by his or her dependents. The service member may elect to serve a shorter tour length by not requesting his or her dependents to accompany him or her to the overseas location. This is not known until after the assignment allocation has been made. Shorter tour lengths are usually associated with assignments that do not allow dependents to accompany their spouses. If the service member does not have dependents, he or she is allowed to serve a shorter length tour than a person accompanied by dependents.

Personnel costs consume a large percentage of the AF budget allocation. This trend is projected to continue. To get the most benefit from each budget dollar, personnel must be utilized as effectively as possible. The cost of training and paying salaries while a person gains proficiency is also large. To minimize this cost, qualified personnel should be retained in the AF as long as possible. Training costs can be minimized by increasing the quality of persons entering the AF, as less training would be required.

AF personnel have continually indicated that they desire some input in their assignment selection. The AF assignment policies have frequently been cited as a major influence in the decision to exit from the AF. AF assignment policies allow the individual to indicate his or her assignment preferences prior to the assignment allocation process being accomplished. A person may volunteer for a location, state or country, or a geographical area. There are many volunteers for California, Germany, and Japan. Few people volunteer for Turkey, Greenland, or Montana. Not all assignments can be filled with volunteers. For this reason, the needs of the AF must come first. There must also be an equitable or fair method of determining who gets what assignment. This must apply to the less desirable and the more desirable assignments.

The frequency with which a person is involuntarily selected to serve in an overseas location varies depending on a person's occupational specialty. In some fields, a person can expect little more than a year in the CONUS before being involuntarily returned overseas. In other fields, a person may spend 30 years in the AF and never go overseas. Frequent, involuntary overseas tours, at locations that are less than desirable, have a negative impact on retention rates in these career fields. Persons entering the AF have many factors influencing their decision to remain in the service. One of these factors is their first assignment.

1.2 ASSIGNMENT PROCESS.

The assignment of people within the AF is governed by policy. Assignment policy is directly affected by such factors as budget constraints, retention problems, and the needs of the AF to place qualified personnel at specific locations in support of operational commanders. These policies change over time. The allocation process must be capable of responding to these changes.

Within the AF, the personnel function allocates and controls the distribution of the total personnel resource. Officers and senior Non-commissioned Officers (NCO) in the two highest grades are manually matched to the jobs they will fill. This is possible due to the small number of people in this category. The remaining 550,000 plus persons are not manually matched to specific jobs for practical reasons. The remainder of this report focuses on the allocation of persons other than officers and senior NCOs in the top two grades. Each individual has an occupational specialty identifier called an Air Force Specialty

Code (AFSC). The AFSC identifies a person's occupational specialty which is called a career field. This same code is used to identify requirements within an AF unit. The AFSC has imbedded within it a skill level indicator. This skill level is comparable to the civilian classification of helper, apprentice, craftsman, and master craftsman or supervisor. The general duties associated with an occupation are described by the AFSC assigned to it. In some jobs, special training or experience is required. To preserve the identity of persons that have received special training or experience, such individuals are assigned a Special Experience Identifier (SEI). Assignments that require this SEI are annotated with the SEI required. For example, if a radioman receives special training, he or she is given a specific SEI. If an assignment requires a radioman with this type of experience or training, a required SEI is indicated. SEIs are generally assigned to a limited number of personnel due to a limited need for this type of special training or experience. If the training is needed by most radiomen, it is included in the AFSC training and an SEI is not used.

To assist in the management of the personnel resource, automation is used where possible. The personnel function has been automated throughout the AF. Each major AF installation has a base level personnel office. A computer, in time-sharing mode, is used by each personnel office to maintain a database on the people it supports. The accuracy of the database is the responsibility of the personnel office at that installation. Specific data items are programmatically copied and transferred to a central location when the data item is changed. These changes update the central database which is maintained by the AF Manpower and Personnel Center.

2.0 CENTRALIZED ASSIGNMENT SELECTION.

A centralized manpower database is located at the AF Manpower and Personnel Center. It contains the required AFSCs, SEIs, and authorized number of personnel for each AF unit. This database is kept current by manpower functions located at AF units having administrative control over subordinate units. This is usually the Major Air Commands (MAJCOM). Each MAJCOM is allocated a specific number of authorizations. These manpower functions are responsible for the distribution of the manpower authorizations to its subordinate units. To increase the number of authorizations in a given unit, it is required that the authorizations in some other unit, within that MAJCOM, are decreased. The MAJCOM also serves as a manning point. The commanders of MAJCOMs can direct that one of his or her units be overmanned at the expense of other units within that MAJCOM. The need for this is usually temporary in nature. Otherwise, the authorizations would be changed permanently in the manpower database. The manning point controls the distribution of personnel within the MAJCOM.

The allocation of personnel resources is done by the AF Manpower and Personnel Center using computer programs. The required data is extracted from the manpower and the personnel databases. The selection process embodies the policies in effect at the time of selection. Computer programs match the assignment requirements with the attributes of those eligible for an assignment. Central allocation insures equitable distribution of the personnel resource between MAJCOMS. The personnel being considered receive impartial consideration for each assignment.

2.1 TYPES OF ASSIGNMENTS:

The allocation process is segmented into assignments to overseas units, and to CONUS units. CONUS units are manned with persons returning from overseas and persons graduating from basic training or technical training schools. Assignment allocations are made monthly during assignment cycles. Assignments are made nine months prior to the month a person is projected to return from overseas or when he or she is needed overseas. Technical training school graduates are assigned as soon as possible after they enter training. The assignment process differs for each category of assignment.

2.2 OVERSEAS ASSIGNMENTS.

When making assignments to overseas units, the allocation process looks for people to fill assignments. The overseas requirements are determined using the personnel database to determine who is scheduled to rotate back from overseas during the specific month being processed that cycle. The manpower database is then examined to determine if the position will exist in the future. If the position is projected to be deleted in the near future, it is not filled. This procedure builds an assignment requirements file. The personnel database is examined to determine who is eligible to be assigned to an overseas location. People are ineligible to be assigned overseas for a variety of reasons. These people are not contained in the personnel eligible for overseas file. The assignment requirements file contains the required AFSC, SEI if any, assignment location, and date required. The personnel eligible for overseas file contains SSAN, AFSC, SEIs if any, volunteer preferences, date they arrived at their current location, the assignment priority which is based on the number of overseas tours previously completed by the individual, and the date they last returned from overseas. A person receives a low assignment priority if he or she has had few overseas tours, and a high priority if he or she has had many overseas tours. If a person has not previously served overseas, the date he or she entered the AF is used as the overseas return date. A person is only considered for assignment in the AFSC he or she possesses. Both files are sorted on AFSC. The personnel file is also sorted on date-arrived current duty station. The assignments are made one AFSC at a time. Persons are selected for an assignment using the following criteria:

1) AFSC match, SEI match if any, volunteer for the assignment, and date-arrived at their current duty station. The person with the oldest date-arrived current duty station is selected first.

2) AFSC match, SEI match if any, assignment priority, and the date returned from overseas. The person with the lowest assignment priority and the oldest return date is selected first.

3) AFSC match, volunteer for the assignment, and date-arrived current duty station. The person with the oldest date-arrived current duty station is selected first.

4) AFSC match, assignment priority, and date last returned from overseas. The person with the lowest assignment priority and the oldest return date is selected first.

If the number of eligible persons is greater that the number of assignments, all assignments are made. If the number of eligible persons is less than the number of assignments to be made, not all assignments are made. The individual is notified that he or she will be considered for overseas assignment two months prior to the assignment cycle. This allows them to update their assignment preferences before they are considered for reassignment.

The assignment process consists of matching the personnel file against the requirements file using criteria one through four above. If a person matches all criteria in one above, the allocation is made. If not, the next personnel record is checked. After all assignments are made using the criteria in one above, the process is repeated using the criteria in two above. If assignments remain unfilled, then the criteria in three above is applied. If not all assignments are filled, then the last criteria is used to fill the remaining assignments. Once an allocation is made, no other person is considered for that assignment.

2.3 CONUS ASSIGNMENTS.

Assignments for persons returning from overseas are basically fixed in number because the date they are projected to return to the CONUS is in the personnel database and is based on a fixed tour length. These assignments are made to find jobs for the people returning from overseas. Ten months prior to the individual's projected return date, they are encouraged to update their assignment preferences. The number of persons in each AFSC for each manning point is known from the personnel database. The number of authorizations for each MAJCOM in each AFSC is known from the manpower database. From these numbers, a percent manned is calculated for each AFSC and MAJCOM. Based on policy, each manning point has an established minimum manning percentage. This is used during the assignment cycle for overseas returnees. An assignment file is built from the manpower database. A personnel file is built from the personnel database. The allocation criteria are:

1) Short tour returnees, AFSC and SEI if any, volunteer status.

2) Long tour returnees, AFSC and SEI if any, volunteer status.

3) AFSC and SEI if any.

4) Short tour returnees, AFSC, volunteer status.

5) Long tour returnees, AFSC, volunteer status.

6) AFSC

The matching process parallels that used to select persons to be assigned to overseas units. To insure the equitable distribution of the personnel resources, the assignments are checked against the MAJCOM manning percentage before an allocation is made. If that MAJCOM is below the minimum manning percentage, the allocation is made and the manning percentage is adjusted. If that MAJCOM is not below the minimum manning percentage, but another MAJCOM is, the assignment is not allocated. Once all minimum manning percentages have been exceeded, the remaining personnel are evenly distributed between the MAJCOMs.

Technical training school graduates are distributed equitably between the MAJCOMs. These allocations are made and forwarded to the training centers where the people are located. Personnel are then matched to the assignments manually. This is necessary because the date that a person will graduate from training is not fixed. The length of the training varies with each AFSC, and some persons complete the training courses faster than others.

After all assignments are allocated, they are forwarded to the MAJCOM manning points for approval or disapproval. Approved allocations are returned and entered into the personnel system. Allocations that are not approved are not entered into the personnel system.

The assignments are made far in advance to give the person selected for reassignment as much advance notice as is possible.

Also, if the person allocated for an assignment is found to be ineligible, time remains for a second person to be selected to fill the assignment. This person would also has sufficient advance notice of the assignment rather than a very short notice. Some assignments are made many times before they are filled.

3.0 MATHEMATICAL PROGRAMMING MODEL.

As assignment policies change, so must the selection process. Lead time for the implementation of a policy change ranges from months to weeks. If the allocation process could be done is such a way that the number of volunteers are maximized there would be fewer people unhappy with the assignment policies. If the number of assignments could be minimized, the assignment costs would be reduced. In both cases the AF would benefit. A cost can be calculated for assigning each person to each assignment and the total cost for an assignment cycle can be minimized using linear programming. Low costs would be assigned to the persons that had the required AFSC and SEI, and were volunteers. High costs would be assigned to a person who had the AFSC, but did not have the required SEI and was not a volunteer. Once a cost is calculated for assigning each person to each assignment , the costs for an assignment cycle can be minimized. The problem can be formulated as a mathematical programming problem. The allocation process can be viewed as a transportation problem. The supply is one, and the demand is one.

Notes on notation: 1) "[" indicates that the variables are to be summed.

2) "[(i)" indicates that the variables are to be summed for i=1,2,....m.

3) "*" indicates multplication.

4) "[(i)R(i,j)" indicates that R is doubly subscripted, and is to be summed for i=1,2,....m.

Formulation of the allocation process for overseas assignments is as follows:

OBJECTIVE FUNCTION: Minimize [(i)[(j) X(i,j) * R(i,j)

SUBJECT TO: [(i)X(i,j) < or = 1, no more than one person per assignment.

[(j)X(i,j) < or = 1, no more than one assignment per person.

VARIABLES: X(i,j) is a decision variable which is equal to 1 if person (i) is selected for assignment (j), 0 if person (i) is not selected for assignment (j).

P(i,g) is a person variable; there are (i) persons, each with (g) factors to be considered in making an assignment.

A(j,k) is an assignment variable; there are (j) assignments, each with (k) attributes.

W(i,j,g) is a weighting variable; for person (i) to be considered for assignment (j), a weight is assigned to each of the (g) factors in the personnel file. This weight is a cost of assigning that person to assignment (j).

V(g) is a set of weights for the (g) factors in the personnel file of a person if he or she is a volunteer and an SEI is not required.

N(g) is a set of weights for the (g) factors in the personnel file of a person if he or she is not a volunteer for the assignment and an SEI is not required.

VS(g) is a set of weights for the (g) factors in the personnel file of a person that has the required SEI and is a volunteer for the assignment.

NS(g) is the set of weights for the (g) factors in the personnel file of a person that has the required SEI but is not a volunteer for the assignment.

W(i,j,g) is built by comparing the A(j,k) to each P(i,g). If person (i) is a volunteer for assignment (j), and has the required SEI, W(i,j,g) = VS(g) for g=1,2,...n. If person (i) is not a volunteer for assignment (j) but has the required SEI, W(i,j,g) = NS(g) for g=1,2,...n. If person (i) is a volunteer for assignment (j) and an SEI is not required, W(i,j,g) = V(g) for g=1,2,...n. If person (i) is not a volunteer for assignment (j) and an SEI is not required, W(i,j,g) = N(g) for g=1,2,...n.

R(i,j) is a cost variable; the cost of assigning person (i) to assignment (j).

R(i,j) = Σ(g)P(i,g)*W(i,j,g) for each (i) and (j).

Using R(i,j) as the cost for each assignment, a linear programming algorithm can be used to minimize the total cost for the assignment cycle. The constraints of no more than one person per assignment and no more than one assignment per person would be checked before the allocation process was begun. Any constraints concerning the eligibility of a person for an assignment have been removed through the use of the program that builds the personnel file.

The same procedure could be applied to the other types of assignments by using a different set of weights for each criteria. For example, a unique set of weights would be used if a person were returning from a short tour area, had the required SEI, and was a volunteer for the assignment. A unique set of weights would be used for each of the criteria used in the assignment process.

3.1 MATHEMATICAL PROGRAMMING ADVANTAGES.

This procedure would improve the assignment selection process by selecting more volunteers for reassignment. For example, a person may be a volunteer for Germany. A second person may be a volunteer for Europe. If an assignment to Germany is processed, and the first person to match the assignment is a volunteer for Europe, no one else is considered for that assignment. If the next assignment that is processed is to Spain, the person that is a volunteer for Germany is not matched. If the assignment to Germany is matched against both persons, and the assignment to Spain is matched against both persons, and the assignment process allowed to minimizes total cost, more volunteers would be selected for reassignment. In the previous example, the person that volunteers for Germany will be assigned to Germany. The person that is a volunteer for Europe will be assigned to Spain. Both persons will be more content with the assignment process because both are volunteers for the assignments they have been selected for.

Other factors can be introduced into the assignment criteria that will benefit the AF by saving money. If a person is moved the shortest distance possible, money is saved. A person stationed in the western part of the US that is a volunteer for a country in Europe and a country in the Far East, can be assigned to the Far East and still satisfy his or her preferences. The money spent to ship that person to Travis A.F.B., California, to depart for the Far East is less than the amount of money required to ship that person to McGuire A.F.B., New Jersy, to to depart for Europe. It is possible to determine if a person can not be granted a security clearance to enable him or her to have access to classified material. This can be used to reduce the number of people selected for an assignment that requires a security clearance and then have the assignment cancelled. This would be helpful in filling assignments that have short leadtimes. If policy allows a person to volunteer to spend a longer tour in an overseas location, the number of assignments over the long term would be reduced. Such volunteers would receive a lower weight for that assignment which would result in the selection of these types of volunteers over other volunteers.

Criteria could be added to the selection process by adding that factor to the personnel file or the assignment file, and adding weights to the weight variables. If the emphasis on a factor is increased or decreased by a policy change, that specific weight can be decreased or increased to change the selection results. This method of selection has greater flexibility because the assignment of the weight can be made to cause a person to be selected or not selected for an assignment.

4.0 AN EXAMPLE.

Attachment one presents a COBOL program written to run on a DECsystem10. The program performs the allocation process described in the mathematical programming formulation with some minor deviations to conserve core memory utilization.

4.1 ASSUMPTIONS.

Tne program assumes:

1) Input data is accurate.

2) Inputs are sorted on AFSC.

3) The date arrived station is the ordinal of the ranking of the eligible person's date-arrived current duty station (DAS). The person who has been on station the longest has the lowest DAS ordinal number.

4)The assignment priority has been correctly calculated in accordance with the guideline presented in the AF assignment manual.

5) The overseas return date is the ordinal of the ranking of the eligible person's date departed the overseas area.

6) Since the current selection criteria is used in the algorithm, R(i,j) is built using a series of IF statements and a weighting variable for each category of personnel. This reduces

the core memory required to accomplish the selection process. [(g)P(i,g)*W(i,j,g) is simulated using the IF statements.

R(i,j) = weight-1 times the DAS ordinal if person(i) has the required SEI and is a volunteer for assignment(j).

R(i,j) = weight-2 times the sum of person(i)'s assignment priority and overseas return date if person(i) is not a volunteer for assignment(j) but has the required SEI.

R(i,j) = weight-3 times the DAS ordinal if person(i) is a volunteer for assignment(j) and an SEI is not required.

R(i,j) = weight-4 times the sum of person(i)'s assignment priority and overseas return date if person(i) is not a volunteer for assignment(j) and an SEI is not required.

7) The P(i,j) matrix has been converted to a vector to further conserve core memory. This is possible since each personnel record is matched with each assignment when the R(i,j) matrix is built. The identifiers for the personnel records are stored in the personnel vector.

8) The X(i,j) matrix has been converted to a vector to further conserve core memory. This is possible since the assignment matrix and the personnel vector can be easily used to identify who should receive which assignment to minimize total costs.

9) The data in the assignment and personnel file were reduced to a workable volume to illustrate the concept presented. The actual files contain over 175 data items.

The selection of weights for V, N, VS, and NS was done to insure that the allocation vector would contain only the allocations that conform to the criteria outlined for CONUS to overseas assignment selection. This treatment of the decision matrix and the person matrix is similar to techniques to handle sparse matrices. The decision matrix would be sparse. A volunteer coding scheme was established that is much less complex than that actually used by the AF due to their large number of locations and geographical areas. This was done to simplify the algorithm. With the coding scheme used, a person can volunteer for any overseas location by using a code of "E" in the first volunteer data element. All other volunteer data elements are blank. A person can state that he or she is not a volunteer by using a code of "0" in the first volunteer data element. All other volunteer data elements are left blank. Up to eight volunteer preferences can be included in the personnel record for an individual. If the code is alphabetic, the person is volunteering for any location in a specific area. If the code is numeric, the person is volunteering for a specific location. A code of "A" indicates that a person is volunteering for locations 1 through 7. A "B" indicates locations 8 through 13. A "C" indicates locations 14 through 20. A "D" indicates locations 21 through 28. This simplistic approach facilitates the coding required to present the algorithm but should not detract from the example. Attachment two presents the assignment file data and the personnel file data. There are 10 assignments to be made from 20 eligible individuals. Attachment three presents the ranking matrix and the decision vector after the program was executed.

4.2 ALLOCATION ALGORITHM.

The solution procedure to obtain the allocation decision vector, is a special case of the transportation problem. The demand is one and the supply is one. The cost matrix (R(i,j)) is the cost of assigning person(i) to assignment(j). The methodology for the selection consists of the following steps:

STEP I: Locate the minimum value in each row of R(i,j). Subtract that value from every element in that row. This is repeated for every row. The same is done for each column of R(i,j).

STEP II: Examine the rows and columns successively. For each row or column with only one zero element, make an assignment to the zero element. Repeat for each row and column until all zero elements are assigned. If all elements are assigned, an optimal solution has been reached. If all assignments have not been made, proceed to STEP III.

STEP III: Cover all non-zero elements with as few lines as possible. Mark all rows that do not have assignments. Next, mark all columns that have zeros in marked rows. Next, mark all rows that have assignments in marked columns. Repeat, until no more rows can be marked. Line off each marked column and each unmarked row.

STEP IV: Examine all elements that are not covered. Select the minimum of the elements and subtract it from the uncovered elements. Add it to the covered row, column intersections.

Repeat STEP II through STEP IV until all assignments are made.

This procedure was presented as a FORTRAN algorithm by Abelardo de Lima Puccini. It is used in the program presented and is contained in attachment four. It was modified slightly to allow it to be used as a subroutine in a COBOL program. No output is performed in the FORTRAN subroutine. The origional algorithm used a subroutine to display the results. In the program presented in attachment one, the allocations are returned to the COBOL program where they are used to build an allocation file.

4.3 ANALYSIS OF THE PUCCINI ALGORITHM.

The Puccini algorithm was found to contain some problems that would prevent it from being used in an actual application. The speed of the algorithm deteriorated rapidly as the number of selections increased. For five assignments and five people, the time required was 0.29 seconds. To make 10 assignment selections from 10 people required 3.89 seconds. To make 10 assignment selections from 20 people required 7.27 seconds. To obtain a starting point for analysis, several values for each weight used to build the cost matrix were tried. The selection of weights to be used in the COBOL algorithm brought to light the fact that the Puccini algorithm did not always find a solution or did not always find a correct solution to the problem. An incorrect solution was obtained when several (2 or more) people had the same characteristics. The algorithm described by Puccini illustrated a solution using a square matrix of costs. The application in this paper will seldom have a square cost matrix. The matrix of costs passed to the Fortran algorithm was set to 999 as an initial value before the assignment costs were calculated and put in the matrix. This forced a square matrix for use in the Puccini algorithm. The selections for the nonexistant assignments were ignored by the COBOL program.

5.0 SUMMARY.

The results of the allocation process are shown in attachment five. Manual verification of the output indicates that the selections made conform to the criteria outlined for overseas allocation of personnel. The problems encountered in the analysis of the Puccini algorithm prevented a level of confidence in the final solution from being obtained. With some weights that were tried, a solution was not obtained in 300 seconds of CPU time. This does not limit the value of this approach to the problem of allocating personnel. An algorithm that does not exhibit these less than desirable characteristics could be developed or obtained to use in allocating personnel resources.

5.1 ADVANTAGES.

The major advantage of this method of allocating personnel is the flexibility it provides. The adjustment of the weights directly affect the selection process. Factors can be added to the selection process to reduce costs to the AF. The screening of personnel to determine who is and who is not eligible may be done in the selection algorithm. The necessary changes would be to include a set of weights that would prevent a person from being selected if he or she did not meet the overseas eligibility criteria. This might allow the selection process to directly interface with the personnel database which would eliminate the need to build the personnel file. This would be a major advantage.

5.2 DISADVANTAGES.

There are disadvantages to this method of allocating personnel resources. The amount of core memory that would be required is large. Some changes could be made, as have been done in the algorithm presented, to conserve core memory. Some AFSCs contain many thousand personnel. This would result in establishing very large upper bounds on the tables and arrays in the program. The core memory requirements may prevent the program from being entered into the processing mix by the operating system. This could be minimized by sorting large AFSCs out and processing them when the operating system will allow very large jobs to be executed. The personnel being selected for reassignment are very sensitive to whom is selected over them, or whom they are selected over. If he or she feels that the process selected them incorrectly, they usually seek verification of their selection in relation to other specific individuals. This is usually done through their congressman. While this is not the reason for following AF policy as closely as possible, it certainly makes the requirement for the programs to be provable a necessity. The only possible way to insure that this algorithm will work in practice is to test it with real data and verify the results. The test data used may have been biased in some manner towards the final selection. This would make the results less than satisfactory. The algorithm selected to perform the allocation process would have to be able to handle matrices that are not square, and should always yield a solution. The speed of the selection algorithm would be an important consideration. With AFSCs that are common to many people, a slow algorithm would not be acceptable.

COBOL program used to allocate personnel resources.

```
IDENTIFICATION DIVISION.
PROGRAM-ID. TEST.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
      SELECT OUT-REC ASSIGN TO DSK
      RECORDING MODE IS ASCII.
      SELECT ASSIGN-FILE ASSIGN TO DSK
      RECORDING MODE IS ASCII.
      SELECT PERS-FILE ASSIGN TO DSK
      RECORDING MODE IS ASCII.
      SELECT VOL-FILE ASSIGN TO DSK
      RECORDING MODE IS ASCII.
DATA DIVISION.
FILE SECTION.
FD VOL-FILE
****  FILE OF DATA TO BUILD TABLE FOR DETERMINING VOLUNTEER STATUS
      VALUE OF ID IS "VOLUNT001"
      LABEL RECORD IS STANDARD
      DATA RECORD IS VOL-AREA.
01 VOL-AREA.
              05 VOL-AREA-CODE                         PIC X(04).
```

```
            05 VOL-LOC1                        PIC X(04).
            05 VOL-LOC2                        PIC X(04).
            05 VOL-LOC3                        PIC X(04).
            05 VOL-LOC4                        PIC X(04).
            05 VOL-LOC5                        PIC X(04).
            05 VOL-LOC6                        PIC X(04).
            05 VOL-LOC7                        PIC X(04).
 FD ASSIGN-FILE
**** FILE OF ASSIGNMENTS TO BE MADE
      VALUE OF ID IS "ASSIGN001"
      LABEL RECORD IS STANDARD
      DATA RECORD IS ASSIGN-REC.
 01 ASSIGN-REC.
            05 ASSIGN-AAN                 PIC X(10).
            05 ASSIGN-AFSC                PIC X(07).
            05 ASSIGN-SEI                 PIC 9(03).
            05 ASSIGN-LOC                 PIC X(04).
 FD PERS-FILE
**** FILE OF PERSONNEL TO BE CONSIDERED FOR ASSIGNMENT
      VALUE OF ID IS "PERSON001"
      LABEL RECORD IS STANDARD
      DATA RECORD IS PERS-REC.
 01 PERS-REC.
            05 PERS-SSAN                  PIC 9(09).
            05 PERS-AFSC                  PIC X(07).
```

```
                    05 PERS-SEI1                    PIC 9(03).
                    05 PERS-SEI2                    PIC 9(03).
                    05 PERS-SEI3                    PIC 9(03).
                    05 PERS-DAS                     PIC 9(04).
                    05 PERS-VOL1                    PIC X(04).
                    05 PERS-VOL2                    PIC X(04).
                    05 PERS-VOL3                    PIC X(04).
                    05 PERS-VOL4                    PIC X(04).
                    05 PERS-VOL5                    PIC X(04).
                    05 PERS-VOL6                    PIC X(04).
                    05 PERS-VOL7                    PIC X(04).
                    05 PERS-VOL8                    PIC X(04).
                    05 PERS-ASSIGN-PRI              PIC 9(02).
                    05 PERS-RET-DATE                PIC 9(04).
  FD OUT-REC
**** OUTPUT FILE
          VALUE OF ID IS "OUTPUTDAT"
          LABEL RECORD IS STANDARD
          DATA RECORD IS PRINT-LINE.
  01 PRINT-LINE          PIC X(130).
  WORKING-STORAGE SECTION.
  01 WS-RANK-MATRIX USAGE COMP.
**** COST MATRIX
          05 WS-ASSIGN-RANK
                    OCCURS 30 TIMES.
```

```
                    10 WS-PERS-ASSIGN              PIC S9(04)
                               OCCURS 30 TIMES.
     01 WS-ASSIGN-MATRIX.
    **** ASSIGNMENT MATRIX
            05 WS-ASSIGN              OCCURS 30 TIMES.
                    10 WS-ASSIGN-NO                PIC X(10).
                    10 WS-ASSIGN-AFSC              PIC X(07).
                    10 WS-ASSIGN-SEI               PIC 9(03).
                    10 WS-ASSIGN-LOC               PIC X(04).
                    10 WS-ASSIGN-ALLOCATE          PIC 9(09).
     01 WS-ALLOC-TABLE USAGE COMP.
    **** DECISION VECTOR
            05 WS-ASSIGN-MAKE                      PIC 9(04)
                               OCCURS 30 TIMES.
     01 WS-PERS-INDEX.
    **** PERSON VECTOR
            05 WS-PERS-SSAN                        PIC 9(09)
                    OCCURS 30 TIMES.
     01 WS-VOLUNTEER.
    **** VOLUNTEER INFORMATION TO CHECK AREAS VOLUNTEERED FOR
            05 WS-VOL          OCCURS 8 TIMES      PIC X(04).
     01 WS-VOL-TABLE.
    **** VOLUNTEER INFORMATION TO CHECK AREAS VOLUNTEERED FOR
            05 WS-GEO-AREA   OCCURS 4 TIMES.
                    10 WS-VOL-AREA                 PIC X(04)
```

```
                              OCCURS 8 TIMES.
01 WS-NUM-PERS  USAGE COMP                        PIC 9(04).
01 WS-NUM-ASSIGN                                  PIC 9(04).
01 WS-TEST                                        PIC X(07).
01 WS-SUB1                                        PIC 9(04).
01 WS-SUB2                                        PIC 9(04).
01 WS-SUB3                                        PIC 9(04).
01 WS-SUB4                                        PIC 9(04).
01 WS-SUB5                                        PIC 9(04).
01 WS-SW1                                         PIC 9.
01 WS-SW2                                         PIC 9.
01 WS-SW3                                         PIC 9.
01 WS-SW4                                         PIC 9.
01 WS-SW5                                         PIC 9.
01 WS-SW6                                         PIC 9.
01 WS-SW7                                         PIC 9.
01 WS-SW8                                         PIC 9.
01 WS-SW9                                         PIC 9.
01 WS-SW10                                        PIC 9.
01 WS-SW11                                        PIC 9.
01 WS-TEMP-SEI                                    PIC 9(03).
01 WS-WEIGHT-1  VALUE 1                           PIC 9(02).
01 WS-WEIGHT-2  VALUE 3                           PIC 9(02).
01 WS-WEIGHT-3  VALUE 6                           PIC 9(02).
01 WS-WEIGHT-4  VALUE 8                           PIC 9(02).
```

```
01 WS-PRINT-REC.
      05 FILLER                                    PIC X(04).
      05 WS-ASGN                                   PIC 9(04).
      05 FILLER                                    PIC X(04).
      05 WS-PERS                                   PIC 9(04).
PROCEDURE DIVISION.
MAIN-LOGIC-PARA.
      PERFORM OPENER-PARA.
      PERFORM VOL-TABLE-BUILD-PARA VARYING WS-SUB1
              FROM 1 BY 1 UNTIL WS-SW4 = 1.
      PERFORM PROCESSING-PARA UNTIL WS-SW1 = 1.
      PERFORM CLOSER-PARA.
      STOP RUN.
OPENER-PARA.
      MOVE ZEROS TO WS-ALLOC-TABLE WS-RANK-MATRIX
              WS-ASSIGN-MATRIX.
      OPEN INPUT ASSIGN-FILE PERS-FILE VOL-FILE.
      OPEN OUTPUT OUT-REC.
      MOVE 0 TO WS-SW1 WS-SW2 WS-SW3 WS-SW4 WS-SW5.
      PERFORM READ-ASSIGN-PARA.
      PERFORM READ-PERS-PARA.
      PERFORM READ-VOL-PARA.
READ-ASSIGN-PARA.
      READ ASSIGN-FILE AT END MOVE 1 TO WS-SW2.
READ-PERS-PARA.
```

```
        READ PERS-FILE AT END MOVE 1 TO WS-SW3.
  READ-VOL-PARA.
        READ VOL-FILE AT END MOVE 1 TO WS-SW4.
  VOL-TABLE-BUILD-PARA.
**** BUILDS THE TABLE TO USE TO CHECK VOLUNTEER STATUS
        MOVE VOL-AREA-CODE TO WS-VOL-AREA(WS-SUB1,1).
        MOVE VOL-LOC1 TO WS-VOL-AREA(WS-SUB1,2).
        MOVE VOL-LOC2 TO WS-VOL-AREA(WS-SUB1,3).
        MOVE VOL-LOC3 TO WS-VOL-AREA(WS-SUB1,4).
        MOVE VOL-LOC4 TO WS-VOL-AREA(WS-SUB1,5).
        MOVE VOL-LOC5 TO WS-VOL-AREA(WS-SUB1,6).
        MOVE VOL-LOC6 TO WS-VOL-AREA(WS-SUB1,7).
        MOVE VOL-LOC7 TO WS-VOL-AREA(WS-SUB1,8).
        PERFORM READ-VOL-PARA.
  PROCESSING-PARA.
**** MAIN PARA TO DO CALCULATIONS
        MOVE ZEROS TO WS-SW4 WS-SW5 WS-NUM-ASSIGN
        WS-NUM-PERS.
        PERFORM SETUP-PARA VARYING WS-SUB1 FROM 1 BY 1 UNTIL
                        WS-SUB1 > 30
                        AFTER WS-SUB2 FROM 1 BY 1 UNTIL
                        WS-SUB2 > 30.
        PERFORM ASSIGN-MATRIX-BUILD-PARA UNTIL WS-SW4 = 1.
        PERFORM RANKING-MATRIX-BUILD-PARA UNTIL WS-SW5 = 1.
        PERFORM SELECTION-PARA.
```

```
        PERFORM ALLOCATE-PARA.
        IF ((WS-SW2 = 1) AND (WS-SW3 = 1))
                MOVE 1 TO WS-SW1.
    SETUP-PARA.
        MOVE 999 TO WS-PERS-ASSIGN(WS-SUB1,WS-SUB2).
    ASSIGN-MATRIX-BUILD-PARA.
**** BUILD THE ASSIGNMENT MATRIX
        MOVE ASSIGN-AFSC TO WS-TEST.
        MOVE 0 TO WS-SUB2.
        PERFORM BUILD-A-MATRIX-PARA VARYING WS-SUB1 FROM 1 BY 1
                UNTIL WS-SW4 = 1.
    BUILD-A-MATRIX-PARA.
**** MOVE THE DATA INTO THE MATRIX
        ADD 1 TO WS-NUM-ASSIGN.
        MOVE ASSIGN-AAN TO WS-ASSIGN-NO(WS-SUB1).
        MOVE ASSIGN-AFSC TO WS-ASSIGN-AFSC(WS-SUB1).
        MOVE ASSIGN-SEI TO WS-ASSIGN-SEI(WS-SUB1).
        MOVE ASSIGN-LOC TO WS-ASSIGN-LOC(WS-SUB1).
        MOVE ZEROS TO WS-ASSIGN-ALLOCATE(WS-SUB1).
        PERFORM READ-ASSIGN-PARA.
        IF ((ASSIGN-AFSC NOT = WS-TEST) OR
                (WS-SW2 = 1))
                MOVE 1 TO WS-SW4.
    RANKING-MATRIX-BUILD-PARA.
**** BUILD THE COST MATRIX
```

```
       ADD 1 TO WS-SUB2 WS-NUM-PERS.
       PERFORM RANKING-FUNCTION-PARA VARYING WS-SUB1 FROM 1
               BY 1 UNTIL WS-SUB1 > WS-NUM-ASSIGN.
       MOVE PERS-SSAN TO WS-PERS-SSAN(WS-SUB2).
       PERFORM READ-PERS-PARA.
       IF ((WS-SW3 = 1) OR(PERS-AFSC NOT = WS-TEST))
               MOVE 1 TO WS-SW5.
 RANKING-FUNCTION-PARA.
**** CALCULATE THE COST
       MOVE 0 TO WS-SW9.
       PERFORM SEI-CK-PARA.
       PERFORM VOL-CK-PARA.
       IF WS-SW6 = 1
               IF WS-SW7 = 1
                       IF WS-SW8 = 1
                               COMPUTE WS-PERS-ASSIGN
                               (WS-SUB1,WS-SUB2) =
                               WS-WEIGHT-1 * PERS-DAS
                       ELSE
                               COMPUTE WS-PERS-ASSIGN
                               (WS-SUB1,WS-SUB2) =
                               WS-WEIGHT-2 *
                               (PERS-ASSIGN-PRI +
                               PERS-RET-DATE)
               ELSE
```

```
                    IF WS-SW8 = 1
                            COMPUTE WS-PERS-ASSIGN
                            (WS-SUB1,WS-SUB2) =
                            WS-WEIGHT-1 * PERS-DAS
                    ELSE
                            COMPUTE WS-PERS-ASSIGN
                            (WS-SUB1,WS-SUB2) =
                            WS-WEIGHT-2 *
                            (PERS-ASSIGN-PRI +
                            PERS-RET-DATE)
        ELSE
                IF WS-SW8 = 1
                        COMPUTE WS-PERS-ASSIGN
                        (WS-SUB1,WS-SUB2) =
                        WS-WEIGHT-3 * PERS-DAS
                ELSE
                        COMPUTE WS-PERS-ASSIGN
                        (WS-SUB1,WS-SUB2) =
                        WS-WEIGHT-4 *
                        (PERS-ASSIGN-PRI +
                        PERS-RET-DATE).
 SEI-CK-PARA.
**** CHECK TO SEE IF SEI REQUIRED AND IF SO, DOES THE PERSON
**** HAVE IT
        IF WS-ASSIGN-SEI(WS-SUB1) NOT = "000"
```

```
                    MOVE 1 TO WS-SW6
                    MOVE 0 TO WS-SW7
                    MOVE WS-ASSIGN-SEI(WS-SUB1) TO WS-TEMP-SEI
                    IF ((WS-TEMP-SEI = PERS-SEI1) OR
                        (WS-TEMP-SEI = PERS-SEI2) OR
                        (WS-TEMP-SEI = PERS-SEI3))
                              MOVE 1 TO WS-SW7
                    ELSE
                              MOVE 0 TO WS-SW7
          ELSE
                    MOVE 0 TO WS-SW6.
  VOL-CK-PARA.
**** CHECK VOLUNTEER STATUS
          IF PERS-VOL1 = "E"
                    MOVE 1 TO WS-SW8
          ELSE
                    IF PERS-VOL1 = "000"
                              MOVE 0 TO WS-SW8
                    ELSE
                              MOVE PERS-VOL1 TO WS-VOL(1)
                              MOVE PERS-VOL2 TO WS-VOL(2)
                              MOVE PERS-VOL3 TO WS-VOL(3)
                              MOVE PERS-VOL4 TO WS-VOL(4)
                              MOVE PERS-VOL5 TO WS-VOL(5)
                              MOVE PERS-VOL6 TO WS-VOL(6)
```

```
                         MOVE PERS-VOL7 TO WS-VOL(7)
                         MOVE PERS-VOL8 TO WS-VOL(8)
                         PERFORM VOL-MATCH-PARA
                         VARYING WS-SUB3 FROM 1 BY 1
                         UNTIL WS-SW9 = 1.
 VOL-MATCH-PARA.
**** FIND LOCATION IN THE AREA VOLUNTEERED FOR
         MOVE 0 TO WS-SW10.
         IF WS-VOL(WS-SUB3) ALPHABETIC
                   PERFORM VOL-AREA-SEARCH-PARA VARYING
                         WS-SUB4 FROM 1 BY 1
                         UNTIL WS-SW10 = 1
         ELSE
                   IF WS-VOL(WS-SUB3) = WS-ASSIGN-LOC
                         (WS-SUB1)
                         MOVE 1 TO WS-SW8.
         IF WS-SUB3 = 8
                   MOVE 1 TO WS-SW9.
 VOL-AREA-SEARCH-PARA.
**** CHECK THE AREA VOLUNTEERED FOR
         MOVE 0 TO WS-SW11.
         IF WS-VOL(WS-SUB3) = WS-VOL-AREA(WS-SUB4,1)
                   PERFORM FIND-LOC-PARA VARYING WS-SUB5
                         FROM 2 BY 1 UNTIL WS-SW11 = 1.
         IF WS-SUB4 = 4
```

```
              MOVE 1 TO WS-SW10.
 FIND-LOC-PARA.
****FIND THE LOCATION IN THE AREA
          IF WS-ASSIGN-LOC(WS-SUB1) = WS-VOL-AREA
                      (WS-SUB4, WS-SUB5)
              MOVE 1 TO WS-SW8 WS-SW9 WS-SW10 WS-SW11.
          IF WS-SUB5 = 8
              MOVE 1 TO WS-SW11.
 SELECTION-PARA.
**** FIND LOWEST COST ASSIGNMENTS
          PERFORM WRITE-OUT-PARA VARYING WS-SUB5 FROM 1
              BY 1 UNTIL WS-SUB5 > WS-NUM-PERS.
          MOVE SPACES TO PRINT-LINE.
          WRITE PRINT-LINE.
          ENTER FORTRAN SOLUT USING WS-PERS-ASSIGN(1,1) WS-NUM-PERS
              WS-ASSIGN-MAKE(1).
          PERFORM WRITE2-OUT-PARA VARYING WS-SUB5 FROM 1
              BY 1 UNTIL WS-SUB5 > WS-NUM-PERS.
          MOVE SPACES TO PRINT-LINE.
          WRITE PRINT-LINE.
 WRITE2-OUT-PARA.
**** WRITE RESULTS OF ALLOCATION
          MOVE WS-SUB5 TO WS-ASGN.
          MOVE WS-ASSIGN-MAKE(WS-SUB5) TO WS-PERS.
          WRITE PRINT-LINE FROM WS-PRINT-REC.
```

```
WRITE-OUT-PARA.
****WRITE COST MATRIX
        MOVE WS-ASSIGN-RANK(WS-SUB5) TO PRINT-LINE.
        WRITE PRINT-LINE.
ALLOCATE-PARA.
**** MAKE ALLOCATIONS
        PERFORM WRITE1-OUT-PARA VARYING WS-SUB5 FROM 1
                BY 1 UNTIL WS-SUB5 > WS-NUM-PERS.
WRITE1-OUT-PARA.
**** UPDATE ASSIGNMENT FILE
        MOVE WS-ASSIGN-MAKE(WS-SUB5) TO WS-TEMP-SEI.
        MOVE WS-PERS-SSAN(WS-TEMP-SEI) TO
                WS-ASSIGN-ALLOCATE(WS-SUB5).
        MOVE WS-ASSIGN(WS-SUB5) TO PRINT-LINE.
        WRITE PRINT-LINE.
CLOSER-PARA.
**** CLOSE FILES
        CLOSE VOL-FILE PERS-FILE ASSIGN-FILE OUT-REC.
```

Z

Attachment Two

ASSIGNMENT FILE

ASSIGN #	AFSC	SEI	LOC
AAN0112345	73270	341	4
AAN0112346	73270		11
AAN0112347	73270	341	21
AAN0112348	73270		1
AAN0112349	73270	101	6
AAN0112350	73270		16
AAN0112351	73270		9
AAN0112352	73270		19
AAN0112353	73270		19
AAN0112354	73270		8

PERSONNEL FILE

```
SSAN        AFSC    SEIs        DAS   VOLUNTEER PREFERENCEs          PRI RET
                                ORD                                      ORD

213645823 73270 34100000000010000                                     01  13
234567891 73270 000000000     8  19  16   8   4  11  21   6          903  10
232345239 73270 000000000    12   A  11  12  20  23   9                7  17
548745891 73270 341000000    17   A  11  12   8                        7  19
342378457 73270 000000000     5   B   1   7  20                        6   9
247964555 73270 000000000    19   D   1  20                            8  11
344523462 73270 000000000     90000                                    5   2
354524341 73270 101000000    18   C                                   10  18
434523238 73270 000000000    13   D   1  20                            2   5
247645569 73270 000000000     4  20   1                               10   8
444234571 73270 000000000    20   E                                    9  20
434519678 73270 341000000    100000                                    7   7
114536286 73270 000000000    16   1  20  17  13  14   2   3       15 5  12
121745329 73270 000000000     7   1  20  17                            0   6
313234567 73270 000000000     3   1  20   3   7                        0   3
114637532 73270 000000000    140000                                    7  16
511354234 73270 000000000    11   A  20                                8   4
220665489 73270 101341000     2  20   1                                4   1
101238542 73270 341000000    15  20   1   7   3                        5  15
501420512 73270 000000000     6   E                                    2  14
```

COST MATRIX

	ASSIGNMENT									
PERSON	1	2	3	4	5	6	7	8	9	10
1	42	112	42	112	42	112	112	112	112	112
2	8	48	8	144	8	8	48	48	48	48
3	12	72	72	72	12	192	72	192	192	192
4	17	102	78	102	17	208	208	208	208	102
5	45	30	45	30	45	120	30	120	120	30
6	57	152	57	114	57	152	152	152	152	152
7	21	56	21	56	21	56	56	56	56	56
8	84	224	18	224	84	108	224	108	108	224
9	21	56	21	78	21	56	56	56	56	56
10	54	144	54	24	54	144	144	144	144	144
11	20	120	20	120	20	120	20	20	20	20
12	42	112	42	112	42	112	112	112	112	112
13	51	136	51	96	51	136	136	136	136	136
14	18	48	18	42	18	48	48	48	48	48
15	9	24	9	18	9	24	24	24	24	24
16	69	184	69	184	69	184	184	184	184	184
17	11	96	36	66	11	96	96	96	96	96
18	15	40	15	12	15	40	40	40	40	40
19	60	160	60	90	60	160	160	160	160	160
20	6	36	6	36	6	36	36	6	36	36

(WEIGHT FOR VOLUNTEER WITH SEI, SEI REQUIRED = 1
WEIGHT FOR NON-VOLUNTEER WITH SEI, SEI REQUIRED = 3
WEIGHT FOR VOLUNTEER, SEI NOT REQUIRED =6
WEIGHT FOR NON-VOLUNTEER, SEI NOT REQUIRED = 8)

PERSON VECTOR

PERSON	SSAN
1	213645823
2	234567891
3	232345239
4	548745891
5	342378457
6	247964555
7	344523462
8	354524341
9	434523238

DECISION VECTOR

ASSIGNMENT	PERSON
1	4
2	14
3	8
4	10
5	18
6	2
7	5
8	20
9	15

10	247645569	10	11
11	444234571	ALL ASSIGNMENTS REQUIRING SEI'S ARE FILLED BY PERSON'S WITH THE SEI. 6 VOLUNTEERS WERE SELECTED.)	
12	434519678		
13	114536286		
14	121745329		
15	313234567		
16	114637532		
17	511354234		
18	220665489		
19	101238542		
20	501420512		

" A FORTRAN Program To Solve The Assignment Problem "

By Abelardo De Lima Puccini

Computer Science Department

Rio Datacenter

Rio De Janerio, Brazil (undated)

```
      SUBROUTINE SOLUT(N,JJ,C)
      INTEGER C(30,30),ATL(30),ATC(30),CUSTO,ALTE
      DIMENSION NZL(30),NZC(30),II(30),JJ(30)
      DO 555 I = 1,N
      NZL(I)=0
      NZC(I)=0
      II(I)=0
      JJ(I)=0
      ATL(I)=0
555   ATC(I)=0
      CUSTO=0
      DO 10 I=1,N
      MIN=32000
      DO 5 J=1,N
      IF(C(I,J)-MIN)4,5,5
4     MIN=C(I,J)
5     CONTINUE
      IF(MIN)6,10,6
6     CUSTO=CUSTO+MIN
      DO 7 J=1,N
```

```
7        C(I,J)=C(I,J)-MIN
10       CONTINUE
C        SUBTRACT THE MINIMUM ELEMENT OF EACH COLUMN
C        FROM EVERY ELEMENT OF THAT COLUMN
         DO 20 J=1,N
         MIN=32000
         DO 15 I=1,N
         IF (C(I,J)-MIN)11,15,15
11       MIN=C(I,J)
15       CONTINUE
         IF(MIN)16,20,16
16       CUSTO=CUSTO+MIN
         DO 17 I=1,N
17       C(I,J)=C(I,J)-MIN
20       CONTINUE
C        OBTAIN THE NUMBER OF ZEROS IN EACH ROW (VECTOR NZL)
C        AND COLUMN (VECTOR NZC). MAKE TRIAL ASSIGNMENTS IN
C        ROWS (VECTOR ATL, JJ) AND COLUMNS (VECTOR ATC, II)
C        THAT HAVE ONLY ONE ZERO ELEMENT.
1        NATR=0
         DO 30 I=1,N
         DO 25 J=1,N
         IF(C(I,J))25,26,25
26       NZL(I)=NZL(I)+1
         NZC(J)=NZC(J)+1
```

```
      IF(NZL(I)-1)27,27,21
27    JJ(I)=J
      ATL(I)=1
      GO TO 22
21    ATL(I)=0
      JJ(I)=0
22    IF(NZC(J)-1)29,29,23
29    II(J)=I
      ATC(J)=1
      GO TO 25
23    ATC(J)=0
      II(J)=0
25    CONTINUE
30    CONTINUE
C     MAKE FINAL ASSIGNMENT WHERE POSSIBLE
C     IN EACH ROW
44    MULT=0
      DO 60 I=1,N
      IF(ATL(I)-1)60,51,60
51    IF(NZL(I))35,60,35
C     ASSIGN IN ELEMENT JJJ OF ROW I
35    JJJ=JJ(I)
      ISUB=I
      CALL ASGNR(ISUB,JJJ,NZL,NZC,II,ATC,NATR)
      CALL ELIM(ISUB,JJJ,C,NZL,NZC,II,JJ,ATL,ATC,NATR,N)
```

```
60      CONTINUE
C       MAKE FINAL ASSIGNMENT WHERE POSSIBLE
C       IN EACH COLUMN
        DO 90 J=1,N
        IF(ATC(J)-1)90,61,90
61      IF(NZC(J))65,90,65
C       ASSIGN IN ELEMENT III OF COL J
65      III=II(J)
        JSUB=J
        CALL ASGNC(III,JSUB,NZL,NZC,JJ,ATL,NATR)
        CALL ELIM(III,JSUB,C,NZL,NZC,II,JJ,ATL,ATC,NATR,N)
90      CONTINUE
C       CHECK TO SEE IF THERE ARE STILL ROW/COLUMNS WITH ONE
C       NON-ZERO ELEMENT AVAILABLE FOR ASSIGNMENT. IF THIS
C       IS THE CASE, THEN REPEAT THE PREVIOUS PROCESS.
        DO 102 J=1,N
        IF(NZC(J)-1)102,44,102
102     CONTINUE
        DO 105 I=1,N
        IF(NZL(I)-1)105,44,105
105     CONTINUE
C       CHECK IF ASSIGNMENT IS COMPLETE
        IF(NATR-N)100,99,99
99      CALL SAIDA(C,N,JJ)
        GO TO 599
```

```
C       CHECK FOR NO MORE  ZERO ELEMENTS
C       AVAILABLE FOR ASSIGNMENT ROW CHECKING
100     DO 130 I=1,N
        IF(NZL(I))126,130,126
126     MULT=1
        DO 110 J=1,N
        IF(ATC(J))110,108,110
108     IF(NZC(J))109,110,109
109     JJJ=J
        GO TO 120
110     CONTINUE
C       ASSIGN ON ELEMENT JJJ OF ROW I
120     ATL(I)=1
        JJ(I)=JJJ
        ISUB=I
        CALL ASGNR(ISUB,JJJ,NZL,NZC,II,ATC,NATR)
        CALL ELIM(ISUB,JJJ,C,NZL,NZC,II,JJ,ATL,ATC,NATR,N)
130     CONTINUE
        IF(MULT)44,138,44
C       OBTAIN THE MIN COVERING LINES TO COVER ZERO ELEMENTS
C       OF THE COST MATRIX.
C       STEP A:
C       MARK ALL ROWS THAT DO NOT HAVE ASSIGNMENTS. THE VECTOR NZL
C       WILL ALSO BE USED TO HELP ON STEP A INORDER TO SAVE CORE.
138     DO 170 I=1,N
```

```
      IF(ATL(I))170,169,170
169   NZL(I)=1
170   CONTINUE
C     STEP B:
C     MARK ALL COLUMNS THAT HAVE ZEROS IN MARKED ROWS. THE VECTOR NZC
C     WILL ALSO BE USED TO HELP ON STEP B.
172   ALTE=0
      DO 180 I=1,N
      IF(NZL(I)-1)180,179,180
179   DO 175  J=1,N
      IF(C(I,J))175,174,175
174   IF(NZC(J)-1)176,175,176
176   NZC(J)=1
      ALTE=1
175   CONTINUE
180   CONTINUE
C     STEP C:
C     MARK ALL ROWS THAT HAVE ASSIGNMENTS IN MARKED COLUMNS
      DO 190 J=1,N
      IF(NZC(J)-1)190,189,190
189   IF(ATC(J))188,190,188
188   III=II(J)
      IF(NZL(III)-1)191,190,191
191   ALTE=1
      NZL(III)=1
```

```
190    CONTINUE
       IF(ALTE)172,193,172
C      SELECTING THE MINIMUM OF THOSE ELEMENTS NOT
C      COVERED BY THE LINES PREVIOUSLY OBTAINED.
193    MIN=32000
       DO 210 I=1,N
       IF(NZL(I))209,210,209
209    DO 200 J=1,N
       IF(NZC(J)-1)201,200,201
201    IF(C(I,J)-MIN)202,202,200
202    MIN=C(I,J)
200    CONTINUE
210    CONTINUE
C      SUBTRACTING THIS MINIMUM FROM ALL OF THE ELEMENTS
C      OF THE COST MATRIX AND ADDING IT TO THE ELEMENTS
C      OF ROWS AND COLUMNS THAT WERE COVERED BY THE
C      LINES PREVIOUSLY OBTAINED.
       DO 220 I=1,N
       CUSTO=CUSTO+MIN
       DO 220 J=1,N
220    C(I,J)=C(I,J)-MIN
       DO 230 I=1,N
       IF(NZL(I)-1)231,230,231
231    CUSTO=CUSTO-MIN
       DO 225 J=1,N
```

```
225     C(I,J)=C(I,J)+MIN
230     CONTINUE
        DO 240 J=1,N
        IF(NZC(J))241,240,241
241     CUSTO=CUSTO-MIN
        DO 235 I=1,N
235     C(I,J)=C(I,J)+MIN
240     CONTINUE
C       THE VECTORS NZL AND NZC SHOULD BE MADE ZERO
C       TO START ALL OVER AGAIN.
        DO 250 I=1,N
        NZL(I)=0
250     NZC(I)=0
        GO TO 1
599     CONTINUE
        RETURN
        END
        SUBROUTINE ASGNR(I,J,NZL,NZC,II,LATC,NATR)
        DIMENSION NZL(30),NZC(30),II(30),JJ(30),LATC(30)
C       THIS SUBROUTINE MAKES AN ASSIGNMENT AT ELEMENT J
C       OF ROW (I).
        NZL(I)=0
        NZC(J)=0
        LATC(J)=1
        II(J)=I
```

```
      NATR=NATR+1
      RETURN
      END
      SUBROUTINE ASGNC(I,J,NZL,NZC,JJ,LATL,NATR)
      DIMENSION NZL(30),NZC(30),II(30),JJ(30),LATL(30)
C     THIS SUBROUTINE MAKES AN ASSIGNMENT AT ELEMENT I
C     OF COLUMN J.
      NZC(J)=0
      NZL(I)=0
      LATL(I)=1
      JJ(I)=J
      NATR=NATR+1
      RETURN
      END
      SUBROUTINE ELIM(K,L,LC,NZL,NZC,II,JJ,LATL,LATC,NATR,N)
      DIMENSION NZL(30),NZC(30),II(30),JJ(30),LC(30,30),
     1 LATL(30),LATC(30)
C     AFTER AN ASSIGNMENT HAS BEEN MADE AT ELEMENT (K,L)
C     THIS SUBROUTINE ELIMINATES OTHER ZERO ELEMENTS IN
C     ROW K AND IN COLUMN L.
C     STEP1 ELIMINATING ZEROS IN COLUMN L
      DO 10 I=1,N
      IF(NZL(I))5,10,5
    5 IF(LC(I,L))10,6,10
    6 NZL(I)=NZL(I)-1
```

```
      IF(NZL(I))9,9,7
9     LATL(I)=0
      JJ(I)=0
      GO TO 10
7     IF(NZL(I)-1)10,11,10
11    LATL(I)=1
      DO 8 J=1,N
      IF(LC(I,J))8,12,8
12    IF(NZC(J))8,8,13
13    JJ(I)=J
8     CONTINUE
10    CONTINUE
C     STEP 2 ELIMINATE ZEROS IN ROW K
      DO 20 J=1,N
      IF(NZC(J))21,20,21
21    IF(LC(K,J))20,22,20
22    NZC(J)=NZC(J)-1
      IF(NZC(J))23,23,17
23    LATC(J)=0
      II(J)=0
      GO TO 20
17    IF(NZC(J)-1)20,24,20
24    LATC(J)=1
      DO 18 I=1,N
      IF(LC(I,J))18,25,18
```

```
25      IF(NZL(I))18,18,26
26      II(J)=I
18      CONTINUE
20      CONTINUE
        RETURN
        END
        SUBROUTINE SAIDA(C,N,JJ)
        INTEGER C(30,30)
        DIMENSION JJ(30)
C       NO OUTPUT IS ACCOMPLISHED IN THIS SUBROUTINE
C       AS IT IS USED IN THIS APPLICATION. THE ORIGIONAL
C       ALGORITHM USED THIS SUBROUTINE TO PRODUCE THE OUTPUT.
        RETURN
        END
```

OUTPUT FILE

ASSGN #	AFSC	SEI	LOC	ALLOC SSAN
AAN0112345	73270	341	4	548745891
AAN0112346	73270		11	121745329
AAN0112347	73270	341	21	354524341
AAN0112348	73270		1	247645569
AAN0112349	73270	101	6	220665489
AAN0112350	73270		16	234567891
AAN0112351	73270		9	342378457
AAN0112352	73270		19	510420512
AAN0112353	73270		19	313234567
AAN0112354	73270		8	444234571

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